CHAPTER 7

SENSITIVITY ANALYSIS

Simulation of a water management system requires input information for soil properties, climatological data, plant relationships, and system parameters, as discussed in Chapter 4. Various methods can be used to measure or approximate these inputs (Chapter 5). The accuracy of the input data will usually be proportional to the time and resources invested in their determination. However, exact values for the required inputs will rarely be available in practice because of measurement errors and field variation of soil properties and other parameters. Results of simulations both in terms of the day-to-day predictions and objective function values (Chapter 3) will obviously be affected by errors in the inputs. Furthermore, the results will probably be affected more by errors in some inputs than others. Therefore, the sensitivity of simulations to errors in the individual inputs is needed in order to establish where priorities should be placed in determining required input data. The purpose of this chapter is to examine the sensitivity of the objective functions to errors in input data for several water management systems.

Procedure

Sensitivity analyses were conducted for the following soils and water management systems:

1. Conventional surface and subsurface drainage on a Lumbee sandy loam at Wilmington, North Carolina.

2. Conventional surface and subsurface drainage on a Toledo silty clay at Columbus, Ohio.

3. Drainage and subirrigation on a Portsmouth sandy loam at Wilmington, North Carolina.

4. Waste water application to a Wagram loamy sand with surface and subsurface drainage near Wilson, North Carolina.

Simulations were conducted and the results presented elsewhere in this report for each of the above cases. Sensitivity analyses are presented in this chapter for a single water management system and operational procedure for each case. That is, only one drain spacing, drain depth, and depressional storage is considered for each soil and location. Drainage system parameters and certain additional input data that were used in sensitivity analyses are summarized in Table 7-1.

Table 7-1. Summary of certain water management system parameters used in sensitivity analyses.

Soil	Location*	Drain Spacing (m)	Drain Depth (m)	Weir Depth** (m)	Depressional Storage (mm)	Reference to Soil Property Information
Lumbee s.l.	Wilmington, N. Carolina	15	1.0	1.0	2.5	Chapter 6, Example Set 1
Toledo sl. cl.	Columbus, Ohio	12.2	0.9	0.9	2.5	Chapter 10, pages 10-37 to 10-44
Portsmouth s.l.	Wilmington, N. Carolina	15	1.0	0.50	2.5	Chapter 6, Example Set 2
Wagram l.s.	Wilson, N. Carolina	30	1.25	1.25	2.5	Chapter 6, Example Set 3

● Location refers to the place that the weather data used in the simulations were obtained. Soil property data may have been obtained from a different location.

** Weir depth is the depth of a weir in the outlet during the growing season. A weir was only used for the Portsmouth soil in the examples considered in this chapter.

Sensitivity analyses were conducted by changing a given input by a predetermined amount, and, with the other inputs held at their correct values, running a simulation for 20 or 25 years of record. Then, values of the objective functions for a 5-year recurrence interval were obtained from the simulation results and plotted as a function of input error. Analyses were made for hydraulic conductivity, water content at the lower limit (or wilting point), upward flux - water table depth relationship, drainage volume - water table depth relationship, root depth, and potential evapotranspiration (PET). For each input parameter, simulations were conducted for the correct value(s) ±10 percent, ±25 percent, ±50 percent, -95 percent, +100 percent, and +200 percent. For example, the hydraulic conductivity for Portsmouth s.l. is (Chapter 6), K = 3.0 cm/hr. Simulations were conducted for K = 3.0 cm/h, 3.3 cm/hr., 2.7 cm/hr, 3.75 cm/hr., 2.25 cm/hr, etc. For layered soils, the conductivity (or other soil property) of each layer was increased or decreased by the given percentage error. Functional relationships, such as drainage volume versus water table depth, were likewise increased or decreased by the given percentage for all levels of the independent variable (water table depth, in this case).

Results

Working Days

Sensitivity of the number of working days predicted by the model to errors in the input data are plotted in Figure 7-1 for Lumbee sandy loam and in Figure 7-2 for Portsmouth sandy loam. Corn production, near Wilmington, North Carolina, was considered in both cases with the seedbed preparation period being from March 15 to April 15, as discussed in the examples in Chapter 6. It may be concluded from Figures 7-1 and 7-2 that errors in hydraulic conductivity (K) have the greatest effect on predicted working days.

An error of +50 percent, in K for the Lumbee soil, would have resulted in a prediction of 17 working days on a 5 YRI, rather than the 11 days that should have been obtained. For the Lumbee soil (Figure 7-1), the sensitivity of predicted working days to errors in drainage (air) volume, PET, and depth to the impermeable layer was of the same order as hydraulic conductivity. Practiced results were not noticeably affected by errors in wilting point or the upward flux relationship. Results for Portsmouth s.l. were only sensitive to negative errors in K and, to a lesser degree, depth to the impermeable layer. The 15 m drain spacing used on the Portsmouth s.l. was chosen to meet both drainage and subirrigation objectives. Actually, a 32 m spacing would have been sufficient to meet the trafficability requirement of 10 working days (Figure 6-15). Because the system is operated in the conventional drainage mode during and prior to seedbed preparation, the maximum number of working days (19), as limited by soil water conditions, was predicted (c.f. Figure 6-15). The other 11 days (30 - 19 = 11) cannot be working days (on a 5 YRI), because of rainfall on those days. Thus, an error causing the K to be too high had no effect on predicted working days for this case. Rapid subsurface drainage provided by the close drain spacing also nullified potential effects of errors in PET, drainage volume, and depth to the impermeable layer.

SEW-30

Effects of errors in soil properties and other inputs on SEW-30 are shown in Figures 7-3, 7-4, and 7-5 for the Lumbee, Toledo, and Portsmouth soils, respectively. In all three cases, SEW-30 was more sensitive to errors in K and PET than to any of the other input parameters. Errors in upward flux and air volume - water table depth relationship had relatively small effects on predicted SEW-30. However, the effects were somewhat greater for subirrigation (Figure 7-5) than for conventional drainage. This is a fortuitous result because the upward flux relationship is usually the most difficult to characterize, and therefore, subject to the greatest error of all the model inputs. The effect of root depth, another input parameter that is difficult to define, also has a relatively small effect on SEW-30 (Figures 7-4 and 7-5).
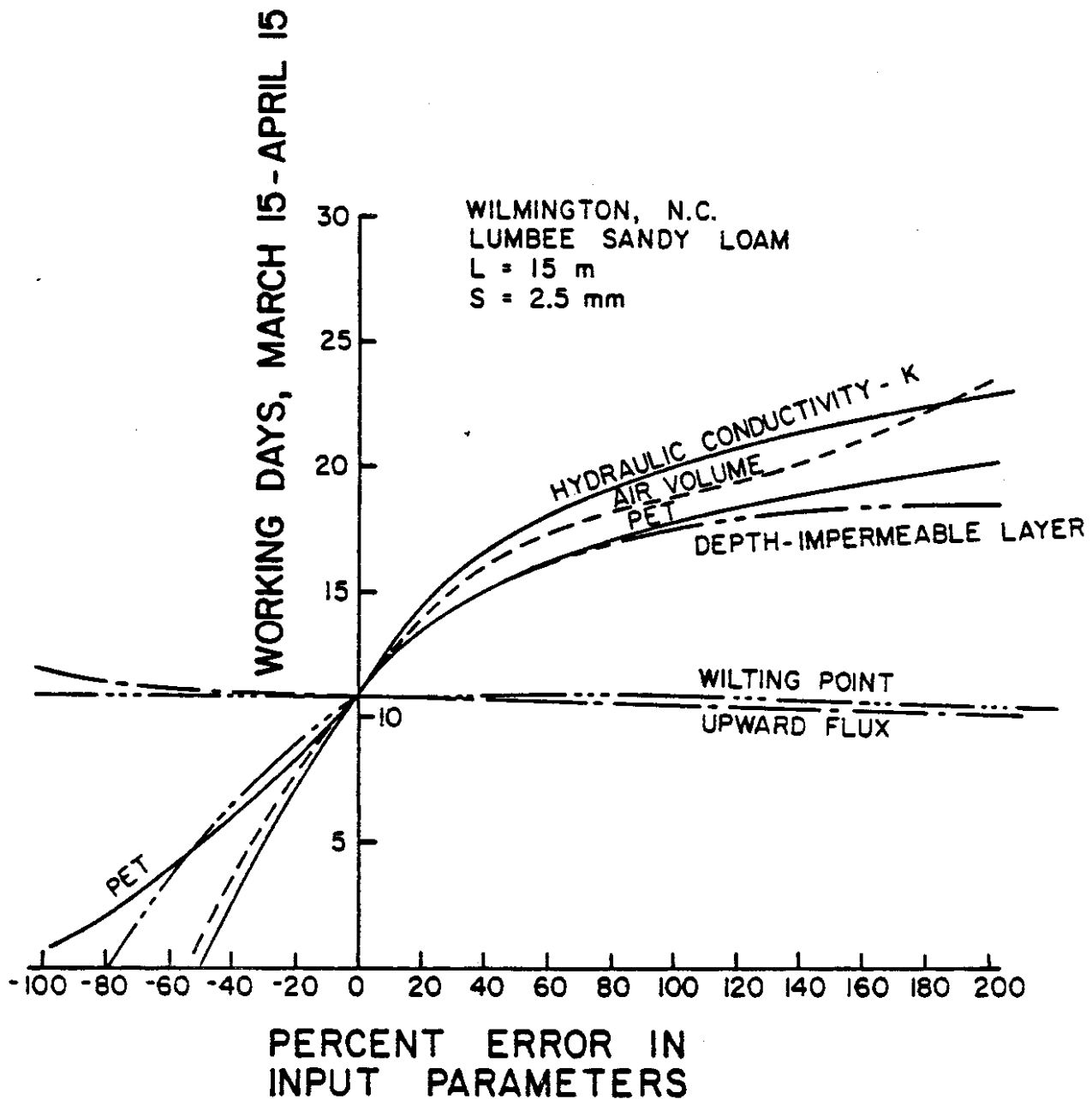
Figure 7-1. Effect of errors in input data on number of working days predicted for the period March 15 to April 15, on a 5-year recurrence interval (5 YRI). Simulations were conducted for a Lumbee sandy loam at Wilmington, North Carolina.
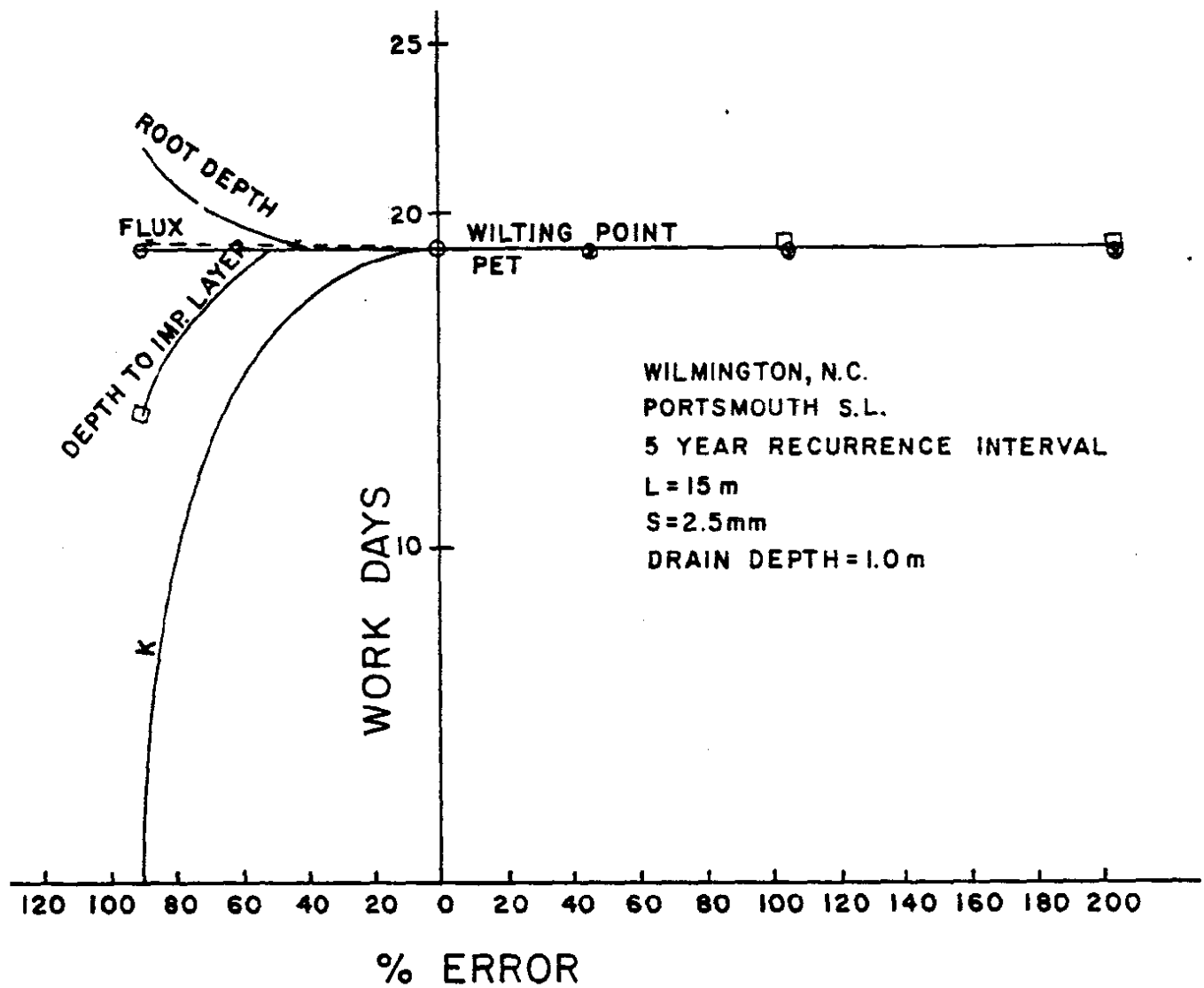
Figure 7-2. Effect of errors in input data on predicted working days for period March 15 to April 15, for Portsmouth sandy loam, at Wilmington, North Carolina.
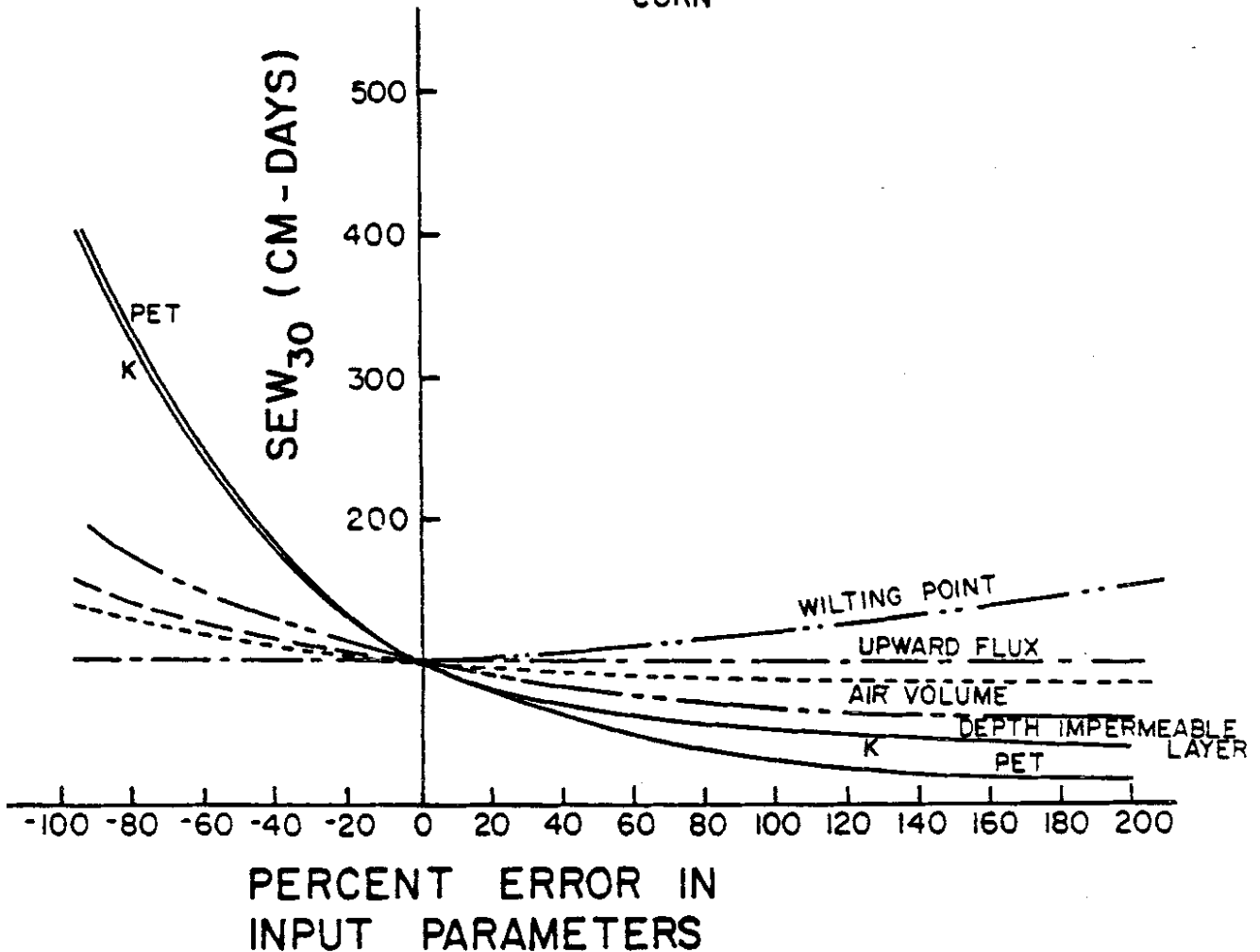
Figure 7-3. Sensitivity of predicted growing season SEW-30 (5 YRI values) to errors in input data for a Lumbee sandy loam, near Wilmington, North Carolina. The water management system was designed for conventional drainage.
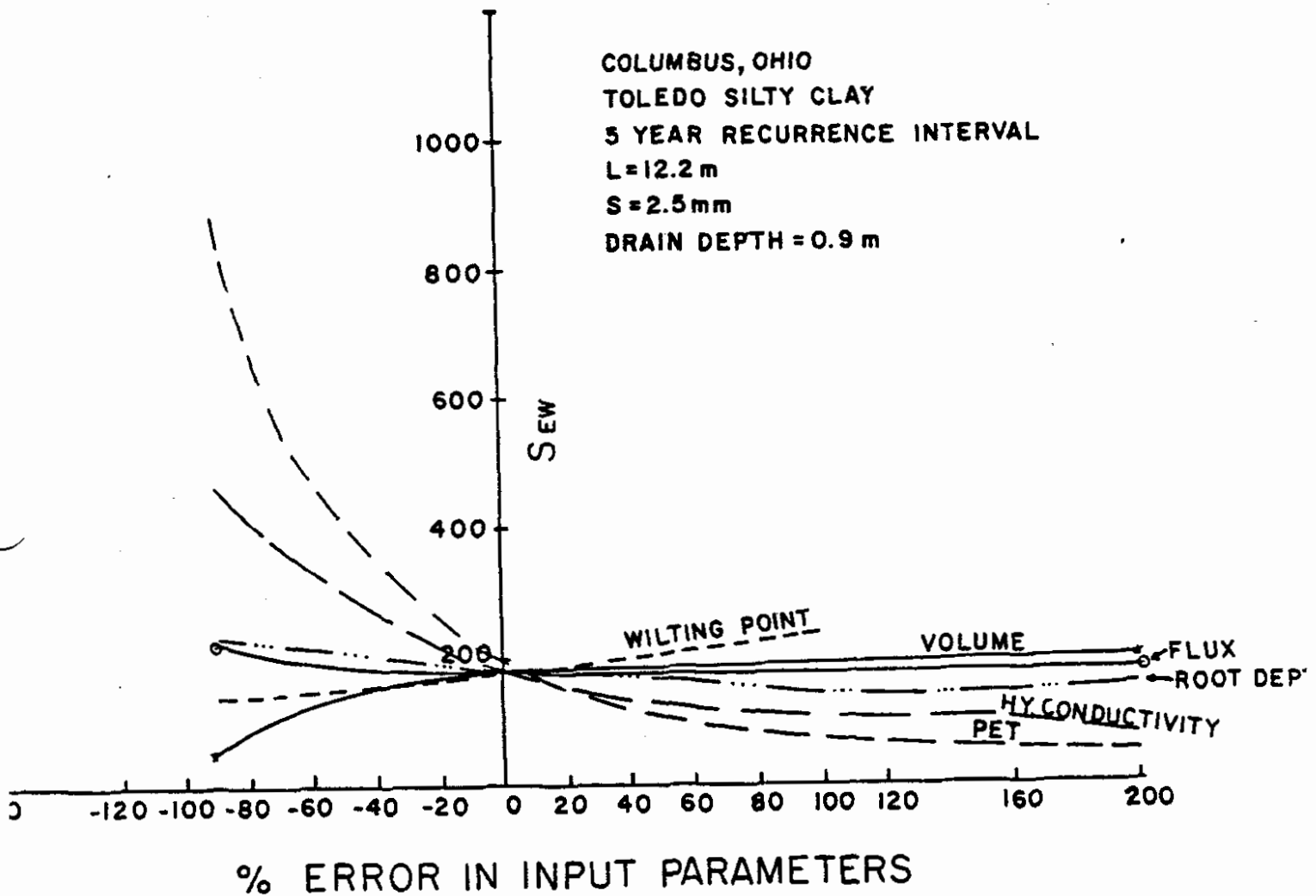
Figure 7-4. Sensitivity of predicted SEW-30 (5 YRI values) to errors in input data for Toledo sl. c., near Columbus, Ohio.
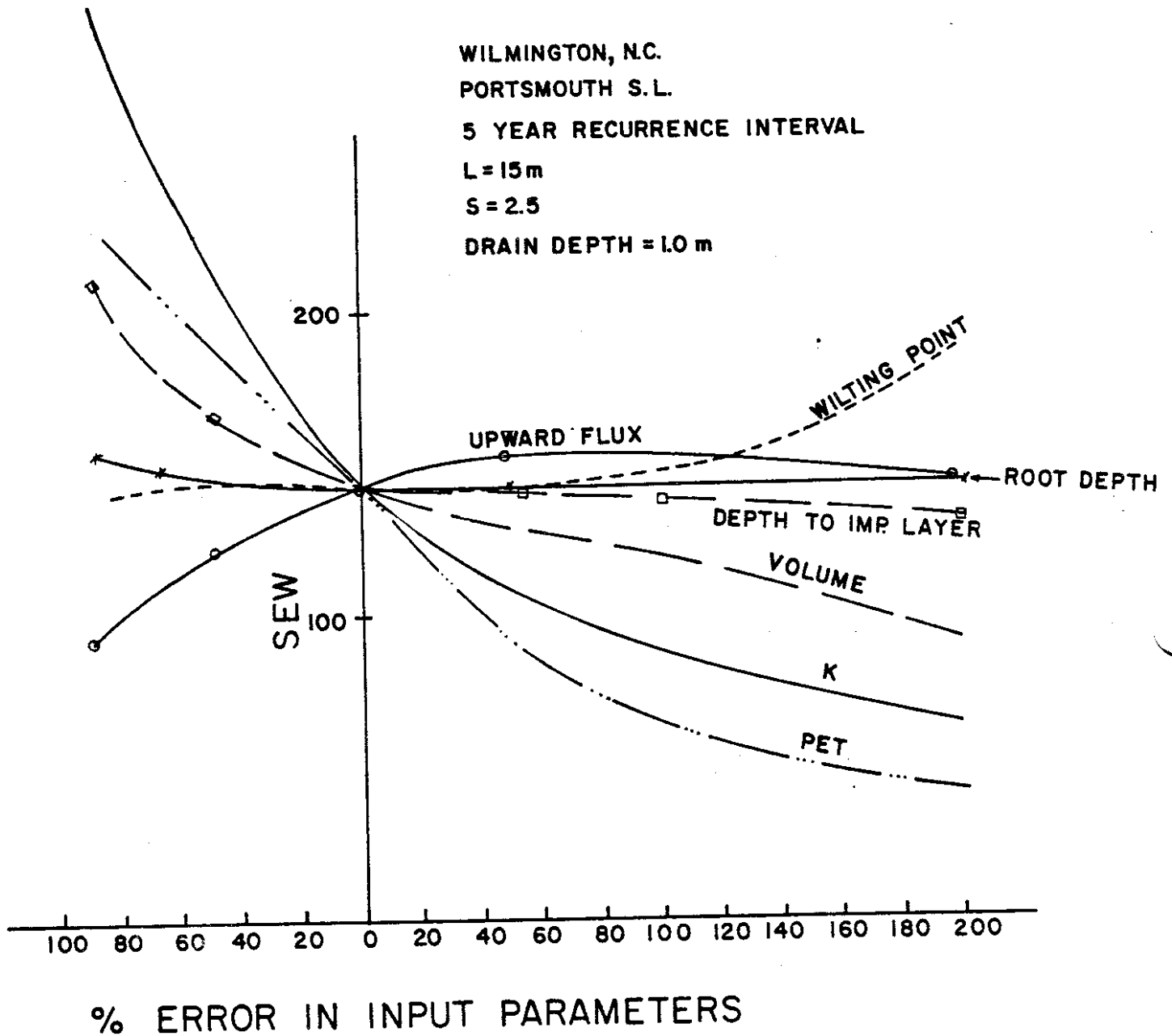
Figure 7-5. Sensitivity of predicted SEW-30 (5 YRI basis) to errors in input data for Portsmouth sandy loam, near Wilmington, North Carolina. Subirrigation was used during the growing season for this case.

Based on the results plotted for working days and SEW-30, effort in defining the model inputs should be concentrated on accurately determining field effective K values and PET. This is especially true when the model is used to analyze conventional surface-subsurface drainage systems. This is not to say, however, that the user can be sloppy in determining the other inputs. The sensitivity analyses presented represent only a limited number of soils, locations, and water management systems. In other situations, the results may be more sensitive to other parameters so all inputs should be specified as accurately as possible.

Dry Days

The sensitivity of the predicted number of dry days to errors in various input parameters is demonstrated in Figure 7-6 for the Lumbee soil near Wilmington, North Carolina, and in Figure 7-7 for the Toledo soil at Columbus, Ohio. In both of these cases, the drainage systems were used for conventional surface and subsurface drainage. The same relationships are plotted in Figure 7-8 for subirrigation on the Portsmouth soil considered in Example Set 2, Chapter 6. The number of dry days are less dependent on K than either working days or SEW-30 for all cases considered. The sensitivity of predicted dry days to errors in root depth and PET was greater than the other parameters tested. For example, there were 36 dry days predicted (5 YRI basis) for the Lumbee soil. If the methods for predicting PET had been 40 percent too high (error of +40 percent), 60 dry days would have been predicted. An error of the same magnitude in effective root depth would have resulted in a prediction of 21 dry days. The effects of errors in root depth were not as great for the Toledo soil or for Portsmouth sandy loam, under subirrigation, as for the Lumbee. Still, the dry days were more sensitive to root depth than any other parameter, except PET.

Dry days were also quite sensitive to errors in the water content at the lower limit (wilting point), except for the case of subirrigation where sufficient water was supplied from the water table so the wilting point selection was not critical. Errors in the upward flux relationship had a significant effect on dry days for Lumbee and Portsmouth soils, but not on the Toledo soil (Figure 7-7). In the latter case, the drainable porosity in the subsoil was small and the water table was often greater than 1 m during dry periods. Since upward flux is small for deep water tables (Figure 10-31), increasing it by as much as 200 percent had only a small effect on the number of dry days. Errors in drainage volume and depth to the impermeable layer had only a small effect on number of dry days predicted.

Waste Water Application

Effects of errors in the model inputs on the predicted annual amount of waste water that can be applied are shown in Figure 7-9 for the Wagram soil considered in Example Set 3, of Chapter 6. The drain spacing is 30 m and irrigation is planned once per week at a rate of 2.54 cm per application. Therefore, the maximum amount that could be applied is 2.54 cm per application. Therefore, the maximum amount that could be applied is 2.54 cm/wk x 52 weeks = 132 cm. The 30 m drain spacing permitted an application of 122 cm on a 5 YRI basis (Figure 6-19), as shown for zero error in Figure 7-9.
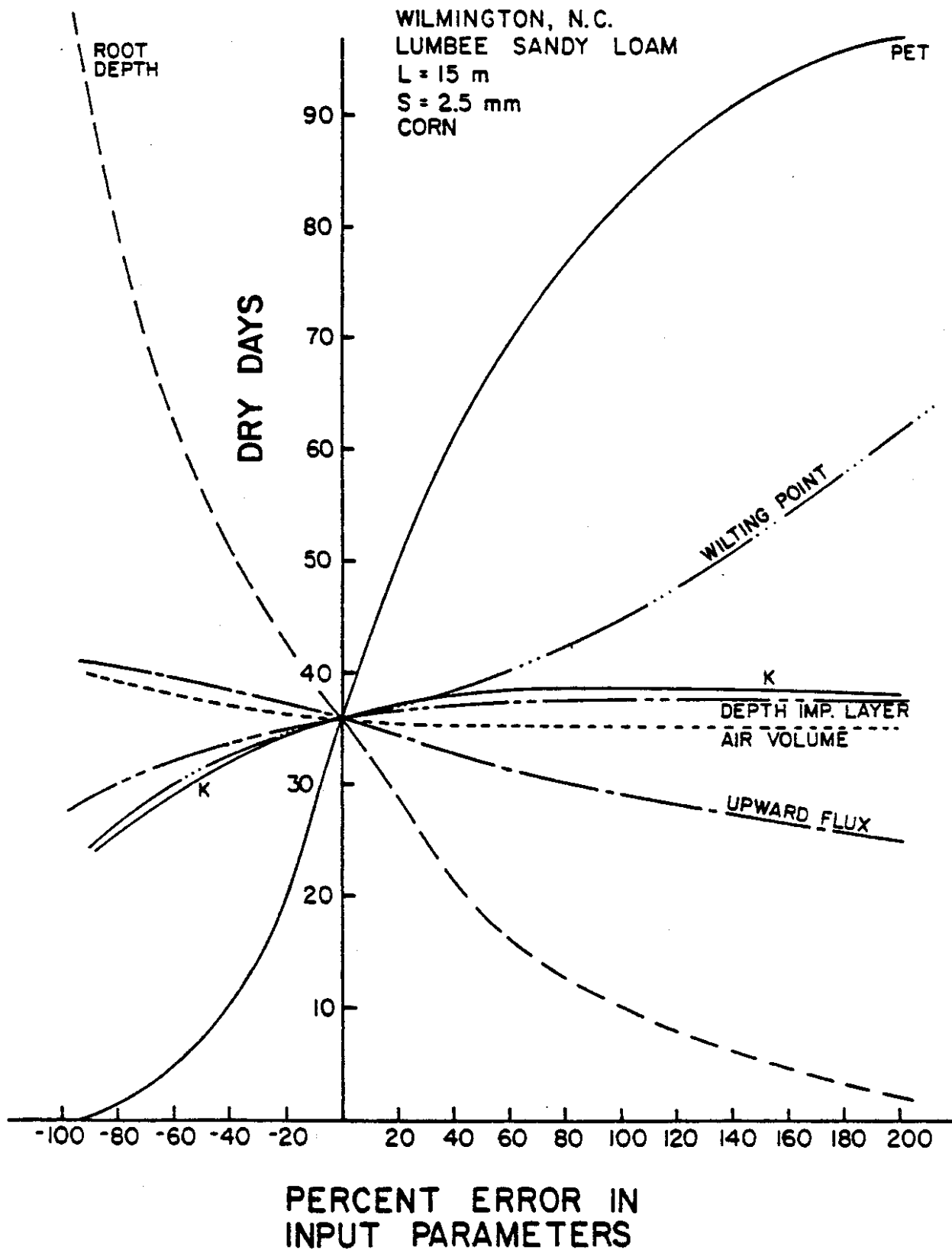
Figure 7-6. Effects of errors in the input data on predicted number of dry days (5 YRI basis) for a Lumbee sandy loam, near Wilmington, North Carolina.
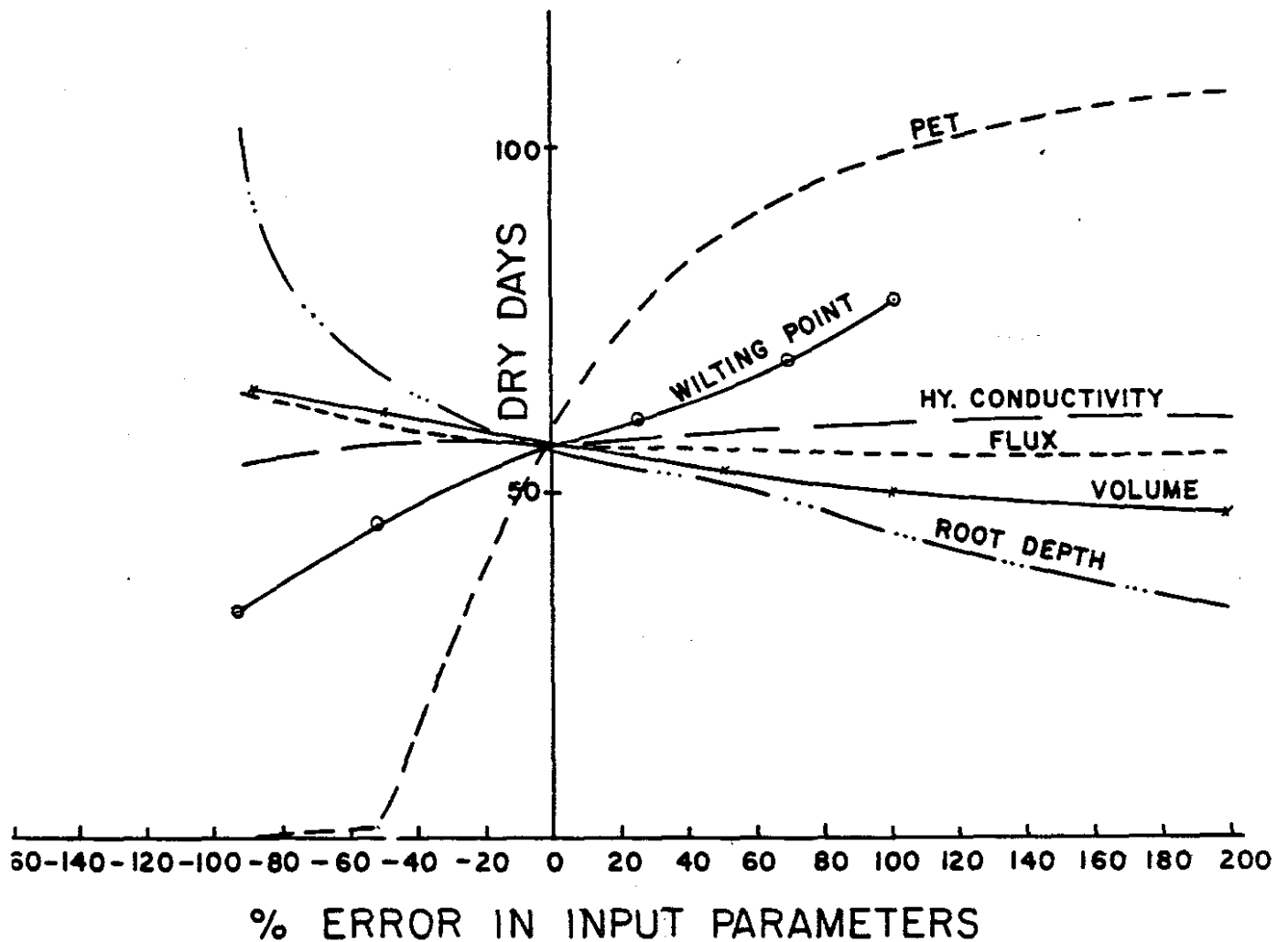
7-11

Figure 7-7. Effects of errors in the input data on predicted number of dry
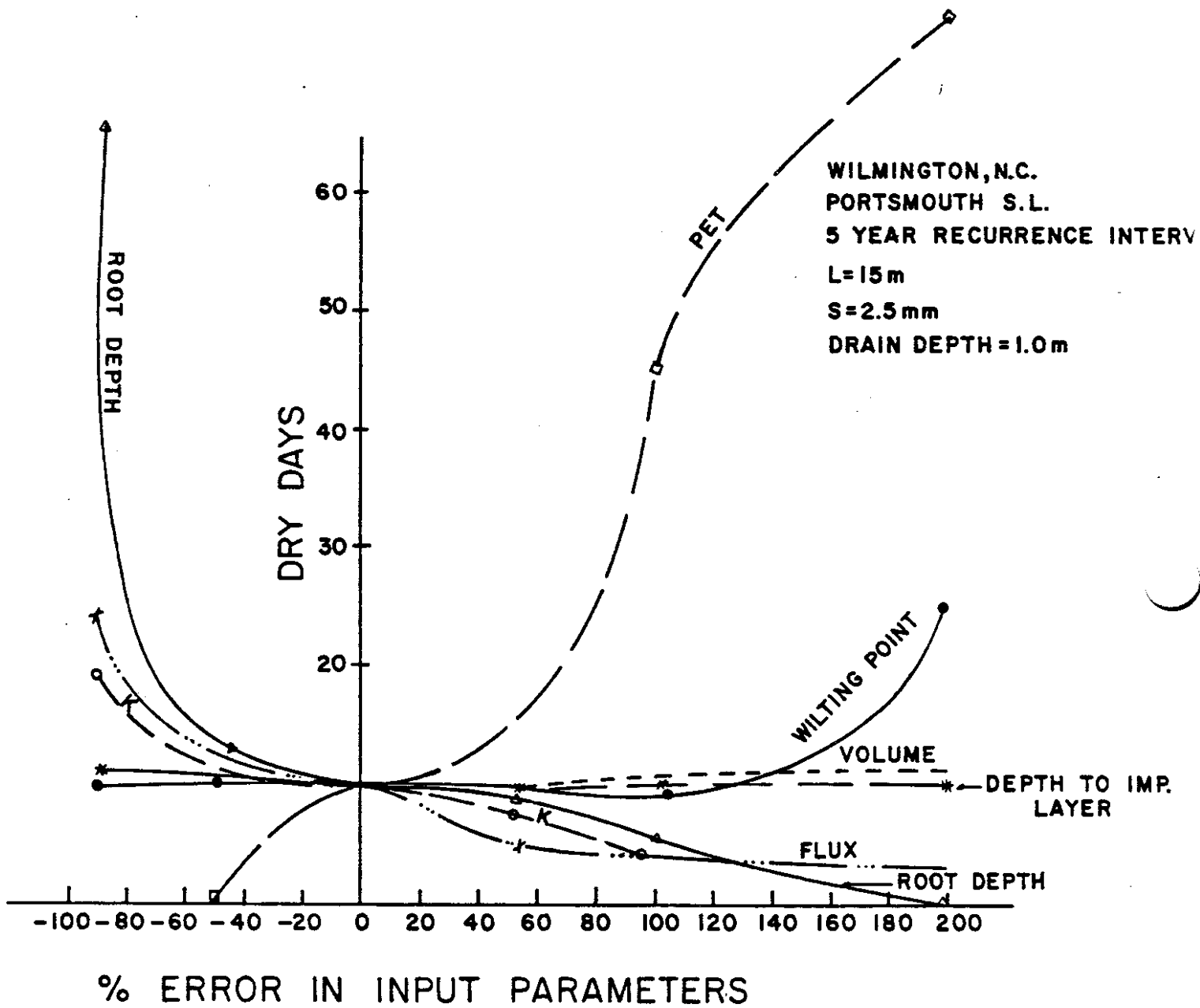days (5 YRI basis) for a Toledo sl. c. located near Columbus,
Ohio.

Figure 7-8. Effect of errors in the input data on predicted number of dry days (5 YRI basis) for subirrigation on a Portsmouth sandy loam, near Wilmington, North Carolina.
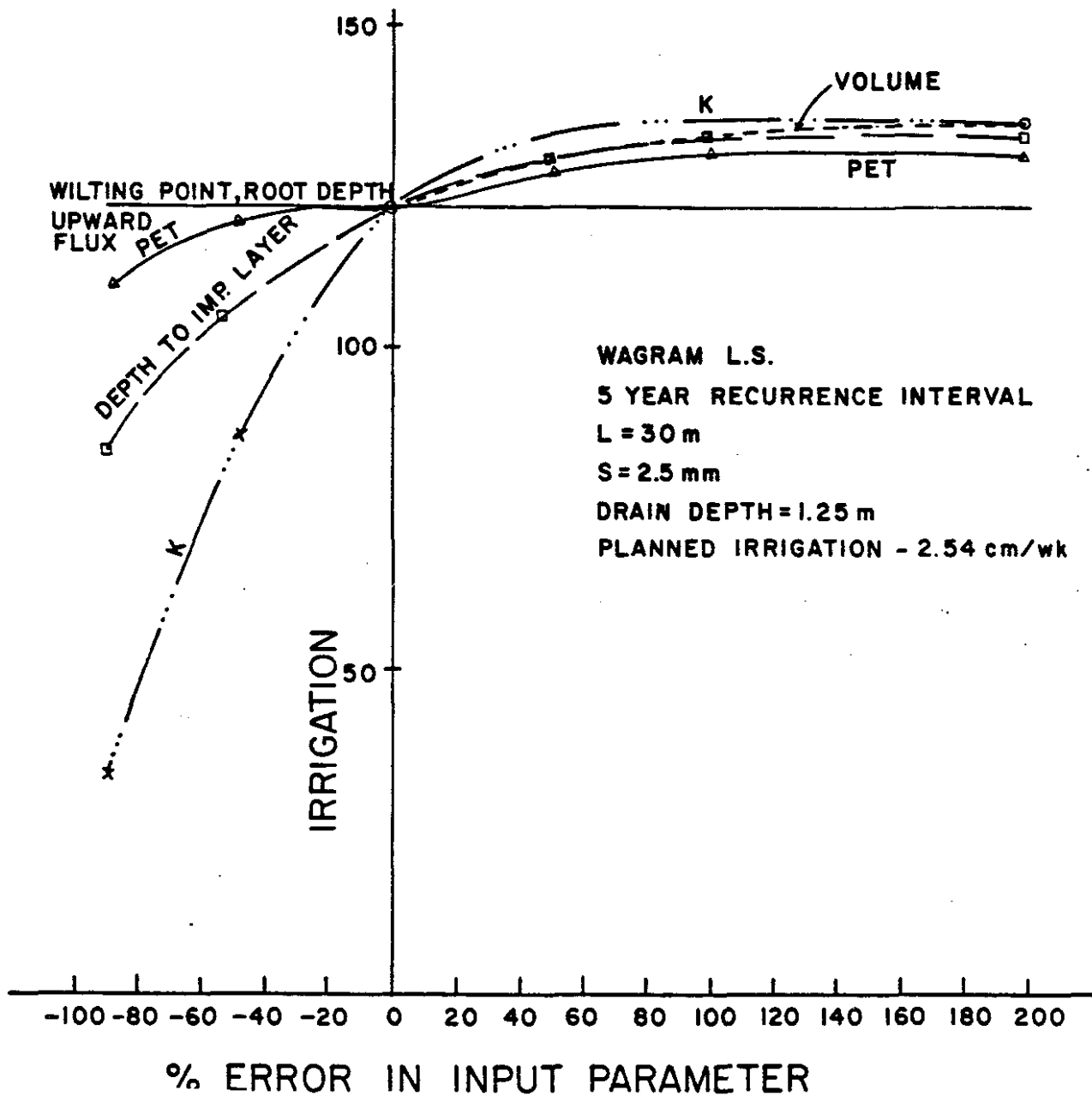
Figure 7-9. Effect of errors in model inputs on predicted total annual
            waste water applied (5 YRI basis) for a Wagram l.s. soil near
            Wilson, North Carolina. Application of waste water is
            scheduled for once per week at 2.54 cm per application.

This waste water treatment system involves application of as much as 2.5 cm per week of water in addition to natural rainfall. Therefore, the soil is relatively wet all year long and the effects of errors in wilting point, root depth, and upward flux relationships on annual waste water application are negligible. Errors in K had the largest effect on the predicted total allowable application. Depth to impermeable layer and PET were the next most sensitive parameters. An error of -50 percent in K (3 cm/hr, rather than 6 cm/hr) would have resulted in a predicted annual application of 86 cm. The same error in depth to the impermeable layer and PET would have given annual amounts of 105 and 128 cm respectively. Thus, if the model is to be used to predict annual waste water application, effort should be concentrated toward determining those input data controlling the rate that the water is removed from the profile: K, depth to the impermeable layer, and PET.